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The Influence of the Distributed Generation to the Distribution Network Line Protection and Countermeasures

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Abstract

This paper analyses the impact of distributed generation on the sensitivity and selectivity of distribution network line protection, proposes the method of using impedance current limiter in solving the impact of the increased current that distribution generation provides on the protection selectivity. Also, gives the position of limiting impedance location and the selection method of the scheme, the feasibility of scheme is verified through an example.

*Keywords:*component; distributed generation; impedance current limiter; protection; sensitivity; selectivity

1. Introduction

In recent years, with the development of power systems, distributed generation (DG) has also got rapid development which has become an important form of electrical energy. China's traditional distribution systems mostly are single power structure and radial form. With the distributed generation's interconnecting, distribution network is no longer a single-supply network, a lot of power and load coexist. It will certainly affect the sensitivity and selectivity of the distribution network protection [1]. Therefore, it is necessary to research the new protection program based on the traditional theory, in the analysis on the basis of these effects. Reference [2-5] analyzed the impact of DG on distribution system relay protection from different angles. Reference [6] proposed the feeder over-current protection scheme for the wide area network-based distribution network with DG, which can not distinguish the fault between the end of the line and at the exit of the adjacent next line. Reference [7] proposed the introduction of fault current limiter into the distribution network. After the fault current was detected, through rapidly changing the impedance parameters of the fault line, it effectively reduced the fault current, ensured the selectivity and sensitivity of the protection. In this paper, based on [7], adopting the improved method of impedance current limiter, can inhibit the DG fault current available, so that the fault line current between after connecting DG and not connecting DG is basically the same. Thus, the failure line circuit breaker meet to cut off the fault

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conditions under the premise of not exceeding the interrupting capacity, and avoid that the short circuit cause great damage to the power system.

2. The Impact of Dg on the Distribution Network Line Protection

2.1 The positive increased role of DG on the its line fault

The instantaneous protection setting values have been determined before connecting the DG, and line protection has had good sensitivity and selectivity. After DG connects the system, when the downstream fault of the DG connecting points occurs, due to the positive increasing role of DG, the fault current of the fault point increases, the sensitivity of protection is improved, the scope of protection is expanded, but it can cause protection loss the selectivity. As the figure 1 shows, After DG connects the system, the fault current through the protection was obviously increased, when the fault current value of the line where the relay 2 is on is greater than the setting value of the relay 1, the relay 1 will act and make the relay loss selectivity.

2.2 The reverse increased role of DG on the adjacent line fault

As shown in Figure 2, after connecting DG, the fault of the adjacent line occurs, DG will provide a reverse increased current. Because the general distribution network is not installed the directional protection devices, when the reverse current is greater than the upstream protection setting value of the DG connecting point, the upstream protection will act, and loss selectivity, this extends the range of power failure.

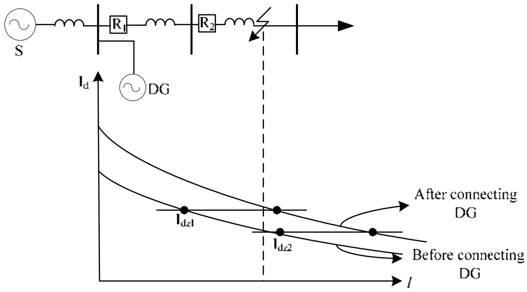

Figure 1. The fault current of the fault point 's change before and after connecting DG.

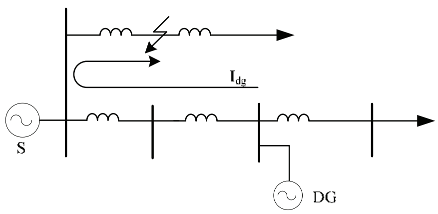

Figure 2. Diagram of the adjacent fault lines.

3. The Location and the Way of Introduced the Impedance Current Limiter

3.1 The location of the impedance current limiter

The location of the impedance current limiter is the common connection point of DG. When there is a fault, it is series with DG. The main role of the impedance current Limiter is to inhibit the DG fault current available.

3.2 Impedance current limiter working

Impedance current limiter relies on power electronics technology to improve responding traditional technologies, so that it achieves current limiting effect.

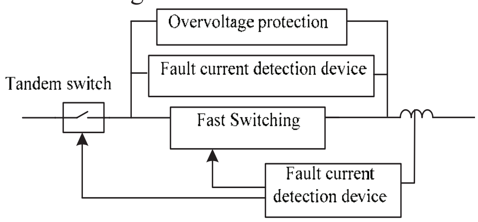

Figure 3. Impedance current limiter block diagram.

As shown in figure 3,it works as follow: the fault current detection device detects the line fault current, once the line faults, fast switching module will limit the value of the impedance from zero to switch to the predetermined value, the impedance current limiter presents a high impedance state, plays a role that limits the fault current. However, under the normal load conditions, its impedance is zero.

4. Introducing Impedance Current Limiter to Sovle The Impact of DG on the Protection

4.1 The introduction of impedance current limiter to solve the role of the forward increased current DG provides

In terms of instantaneous relay, the scope protection of DG not only determine the selective of protection but the sensitivity of that, so the impedance current limiter can be introduced at the DG side, to inhibit the fault current available which is provided by DG, to ensure that the original scope of protection is essentially the same, to prevent protection from the loss of selectivity.

Instantaneous relay setting value is based on the maximum operating mode of the escaping the maximum three-phase short-circuit current of the end of the line to set:

$$I_{dz} = \frac{KE_{\varphi}}{Z_{s\min} + Z_d} \tag{1}$$

Where: K is a reliable factor in the range of 1.1 to 1.3; E_{φ} is the system phase voltage; $Z_{s\min}$ is the short-circuit impedance of the system maximum operating mode; Z_d is the line impedance.

In general, the sensitivity of instantaneous relay weighs with its protection scope measure, which was expressed as [8]:

$$\alpha = \frac{K_d(Z_{s\min} + Z_d) - KZ_{s\max}}{KZ_d} \tag{2}$$

Where: α is the protection scope, K_d is the fault type coefficient, $Z_{s\max}$ is system short-circuit impedance in the minimum operating mode.

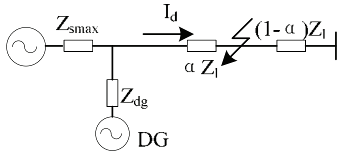

Figure 4. The line fault of distribution network with DG diagram.

As shown in figure 4, if you want to ensure that the original scope α of protection unchanged, the end of protected area has a fault, fault current equals protection setting:

$$\frac{I_d}{I_{set}} = \frac{I_d}{K_{dg} I_{dz}} = \frac{K_d E_\varphi \Big/ \left[Z_{s\max} Z_{dg} / (Z_{s\max} + Z_{dg}) + \alpha Z_l \right]}{K_{dg} K E_\varphi \Big/ (Z_{s\min} + Z_l)} = 1 \tag{3}$$

$$\gamma \frac{(Z_{s\min} + Z_l) Z_{dg} + (Z_{s\min} + Z_l) Z_{s\max}}{(Z_{s\max} + \alpha Z_l) Z_{dg} + \alpha Z_l Z_{s\max}} = 1 \tag{4}$$

Where: $\gamma = K_d / (K K_{dg})$, I_d is the fault current of DG downstream protection, K_{dg} is protection correction factor after connecting DG, Z_{dg} is the impedance of the common connection point of DG. From (4), $K_{dg} = 1$, the sensitivity of protection will increase, protect scope potentially expands and may exceed limited value, the protection may loss selectivity. Therefore, adding impedance current limiter at the DG side, reasonably selecting a limited resistance Z_f , controlling the impact of DG operation mode on the protection within an acceptable range.

According to (4), it can be derived:

$$K_{dg} = \frac{(Z_{s\min} + Z_l)(Z_{dg} + Z_{s\max})}{(Z_{s\min} + Z_l)(Z_{dg} + Z_{s\max}) - K Z_{s\max}^2 \big/ K_d} \tag{5}$$

By (5), introducing the impedance current limiter, Z_{dg} increases, K_{dg} gets smaller, the amendment value of protection decreases, because DG 's impact on protection will gradually decrease as the line impedance increase, so the value of impedance current limiter is determined by the line protection parameters which is near the DG connection point. Through the above analysis, the impedance current limiter can effectively limit the increased current of DG. Furthermore, the value of protection modified by the impedance parameters, well ensure the selectivity and sensitivity of protection.

4.2 The introduction of impedance current limiter to solve the role of the reverse increased current DG provides

As shown in Figure 2, when the reverse increased current DG provides is too large, it easily makes the protection of DG upstream lose selective. Because DG capacity connecting into distribution networks generally does not exceed 15MW, for the impact of reverse increased current DG provides, As long as the reverse increased current DG provides is less than of the value of the upper time limit protection,

protection will be able to maintain coordination. Then the value of impedance current limiter can be expressed as:

$$Z_f > \frac{E_{dg}}{I'_{set}} - Z_{DG\min} \tag{6}$$

Where: E_{dg} is the DG voltage when fault occurs, $Z_{DG\min}$ is the minimum impedance of the DG operation.

In summary, the introduction of impedance current limiter at the DG side, avoids adverse effects of DG to the protection, ensures the sensitivity and selectivity of the protection.

5. Example Analysis

We make 10kV distribution network in Figure 5 for example, base capacity of 30MVA, the reference voltage of10kV, distribution network parameters (standard per unit) are shown in the diagram, the load of the end is equivalent to constant impedance load, the impedance of 10.17, DG capacity of 5MVA, the maximum operation mode $X_{DG\min} = 0.75$, the minimum operation mode $X_{DG\max} = 0.9$.

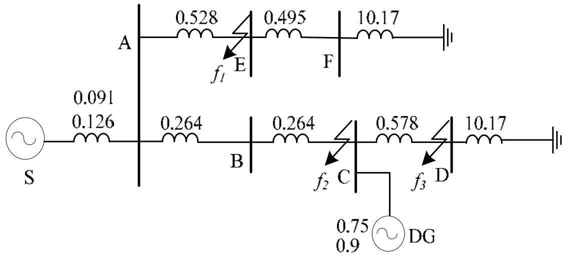

Figure 5. The actual distribution network of 10kV.

Based on the above parameters, Table 1 and Table 2 lists fault current of the maximum operation mode and minimum operating mode respectively when the three-phase short circuit fault occur on the line end, when no DG connects into system and DG connects into system without installing impedance current limiter.

TABLE I. THE FAULT CURRENT WITHOUT CONNECTING DG

fault point	**fault current(A)**	
	the maximum operation mode	***the minimum operating mode***
end of AE (f_1)	2162.20	1911.70
end of BC (f_2)	2439.44	2220.51
end of CD (f_3)	1247.84	1157.75

TABLE II. THE FAULT CURRENT WHEN DG CONNECTS INTO SYSTEM WITHOUT INSTALLING IMPEDANCE CURRNET LIMITER

fault point	**fault current (A)**	
	the maximum operation mode	***the minimum operating mode***
end of AE ($f1$)	2871.66	2684.04
end of BC (f_2)	4747.99	4144.68
end of CD (f_3)	1749.32	1737.20

Analysis of Table 1 and Table 2, after DG connects into system, the three-phase short-circuit current of the line end was significantly increased, which increases the sensitivity of protection, so that the protection scope is expanded, but it may also make the protection lose selectivity, resulting in protection malfunction.

According to the proposed protection scheme that the introduction of impedance current limiter, substituting the various parameters into (4) 、(5) and (6), we have $Z_f = 2.25$. Fault current here are shown in Table 3. It can be seen from Table 3, after adding impedance current limiter, the three-phase fault current at the end of the line basically restores to the level when no DG adds to system. We make the protection setting value without DG multiplied by the correction factor to meet the current protection with impedance current limiter. Adding impedance current limiter is used to limit the DG fault current, avoid the impact of adding the DG on the entire distribution network protection.

TABLE III. THE FAULT CURRENT WHEN DG CONNECTS INTO SYSTEM WITH INSTALLING IMPEDANCE CURRNET LIMITER

fault point	**the fault current after adding impedance current limiter (A)**	
	the maximum operation mode	***the minimum operating mode***
end of AE *(f_1)*	2165	2047.22
end of BC *(f_2)*	2733.10	2541.05
end of CD*(f_3)*	1271.29	1207.20

In summary, after connecting DG into the system, the DG forward increased current allows the system fault current increased, selective of system protection lost. After adding impedance current limiter, the system line fault current basically restored to the level without adding DG, thus it ensures the normal operation of the original system of protection to meet the tuning requirements.

Conclusion

In this paper, we study the solution that makes the fault current increased after connecting DG, namely: the introduction of impedance current limiter at the DG side, by comparing short-circuit current before and after joining DG, reasonably set the impedance current limiter value, make the system short-circuit current after adding DG return to the level before joining DG. Thus ensure the right action of the original protection, and testify that the feasibility of using impedance current limiter by a factual example.

References

[1] ZHANG Yanxia, DAI Fengxian. New scheme of feeder protection for distribution networks including distributed generation[J]. Automation of Electric Power Systems, 2009，33(12) :71-74.

[2] ZHANG Chao, JI Jianren, XIA Xiang, et al. Effect of distributed generation on the feeder protection in distribution network[J]. Relay, 2006, 34(13): 9-12.

[3] HUANG Wei, LEI Jinyong, XIA Xiang, et al. Influence of distributed generation on phase-to-phase short circuit protection in distribution network[J]. Automation of Electric Power Systems,2008, 32(1): 93-97.

[4] GAO Yan, BI Rui, YANG Wei, DING Yin. Effect of Distributed Generation on Relay Protection in Distribution System[J]. Power System and Clean Energy, 2009, 25(4): 20-23.

[5] PANG Jianye, XIA Xiaobin, FANG Mu. Impact of distributed generation to relay protection of distribution system[J].Relay, 2007，35(4)：5-8.

[6] LING Xia, LU Yuping, WANG Lianhe. New current protection scheme considering distributed generation impact[J]. Automation of Electric Power Systems, 2008, 32(20): 50-56.

[7] WU Gang, LU Yuping, HUA Lidan. Impact of fault current limiter to the performance of relay protection in distributed generation[J]. Jiangsu Electrical Engineering, 2007, 26(2): 1-4.

[8] DOYLEMT. Reviewing the Impacts of Distributed Generation on Distribution System Protection[C]. Power Engineering Society Summer Meeting, 2002.